ENGINEERING A SAFE ROAD SYSTEM, STRATEGIC FRAMEWORK APPLICATION

Brendan Marsh, Main Roads Western Australia

Abstract

Main Roads Western Australia's highest value road project, the New Perth Bunbury Highway, aspired to achieve world class outcomes, including significant reductions in serious injury and death through innovative road engineering. An innovative strategic process was employed including broad stakeholder engagement, the formation of an independent 'Safe System Working Group' and a "Vision Zero" Workshop that attracted experts from other jurisdictions (including Sweden). A valuable product of the process was a 'Vision Zero' Logical Framework and significant road safety innovations being applied to the project (e.g. an enhanced intersection collision warning system). The 'Vision Zero' Logical Framework was awarded the prestigious IPWEA Innovative Practice in Traffic Safety and Management Award.

1. INTRODUCTION

Main Roads Western Australia (MRWA) is the State road transport agency, with responsibility for some 17 800km of major roads, all traffic signals and all regulatory road marking and signage in Western Australia. The New Perth Bunbury Highway (NPBH) is Main Roads highest value road project and involves the construction of 32km of Freeway and 40km of dual carriageway highway, providing a direct connection between Perth (via Kwinana Freeway) and Bunbury, bypassing the congested Mandurah city, residential, retail and industrial precincts.

In the delivery of the construction, MRWA entered into an alliance with Leighton Holdings, GHD and WA Limestone, creating the Southern Gateway Alliance (SGA). MRWA set ambitious aspirations for the SGA in accordance with a sustainability framework covering Key Result Areas, for example, 'Sustaining Network Operations' (SNO), 'Environment' and 'Asset Management'.

The Key Result Areas were weighted to represent their priority for MRWA and the relative level of effort intended for the SGA to achieve a better project outcome than "business as usual". SNO received the highest ranking out of all the Key Result Areas and represented the network operation outcomes, for example, Road Safety, transport efficiency and Intelligent Transport Systems.

Minimum conditions of satisfaction were assigned to the subcategories within the Key

Result Areas, often requesting outcomes better than “business as usual”. For example, the minimum condition of satisfaction for Road Safety required a 10% reduction in serious injury and death when compared to equal standard roads. In addition, aspirational targets were developed to further encourage innovative thinking.

To enable the SGA to pursue the aspirational targets, a sustainability and partnerships team was formed. It’s purpose was to engage with stakeholders and the community and to find innovations that would bring the SGA closer to achieving the aspirational targets. One of focal areas within the team was SNO.

A Stakeholder Reference Group was established for SNO which included three major workshops and a series of working group discussions established to focus upon the areas within SNO. One of the key areas was Road Safety and the third SNO workshop recommended that MRWA establish a Safe Systems Working Group (SSWG) to independently provide advice to the SGA.

MRWA accepted the recommendation and invited Engineers Australia to independently chair the SSWG, for which respected engineer, Mr Sarkis Petrossian was nominated. The other members of the SSWG included Mr Des Snook (Executive Director Road Network Services, MRWA), Mr Iain Cameron (Executive Director, Office of Road Safety), Mr David Moir (Executive Director, Royal Automobile Club), Mr Ashley Wright (Engineering Manager, SGA), Mr Antony Missikos (Sustainability and Partnerships Manager, SGA and MRWA), Mr Brendan Marsh (Sustaining Network Operations Team Leader, SGA and Network Operation Engineer, MRWA) and Mr Linton Pike (Estill and Associates – independent facilitator). The SSWG met 17 times, developed the ‘Vision Zero’ Logical Framework (VZLF) and conducted a ‘Vision Zero’ workshop including national and international experts in road safety.

The following paper explains the VZLF development, the key process elements applied by the SSWG and the application of the VZLF which includes examples of achievements at NPBH and other jurisdictions. The paper recommends the application of the VZLF to all projects so that further innovations can be identified to enable sustainable reductions in serious injury and death through road engineering.

2. ROAD SAFETY ASPIRATION AND COMPETING OBJECTIVES

Road authorities are responsible for managing diverse and competing objectives. For example, MRWA's annual community survey's constantly notes that Road Safety has the highest 'community importance score' with other competing road network performance objectives also regularly receive significant scores (see figure 1). This demonstrates that road authorities are often faced with difficult decisions when options to improve an objective like road safety would detract from other outcomes in other objective areas. The challenge is to find 'win-win' solutions that produce benefits across all objectives.

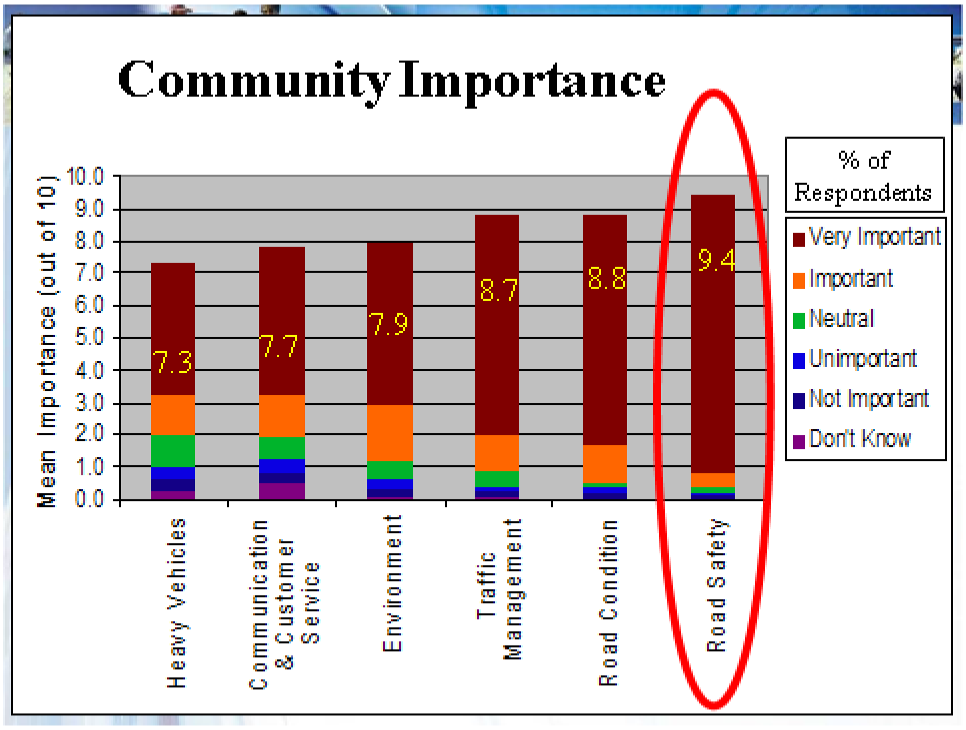

Figure 1: MRWA community importance of competing objectives, with Road Safety receiving the highest score of 9.4 out of 10[1].

The proposed road safety strategy, 'Towards Zero', provides an inspiring road safety vision:

> 'A road transport system where crashes resulting in death or serious injury are virtually eliminated', and
>
> the 'Strategy Cornerstones' are 'Safe Road Use', 'Safe Roads and Roadsides',

[1] Main Roads Community Survey 2008.

‘Safe Speeds’ and ‘Safe Vehicles’[2].

It is important to observe that the strategy vision specifically seeks virtual elimination of ‘death or serious injury’ because some existing road safety programs include less severe crash types within their criteria. There are many ways in which road authorities will be critical to the successful achievement of the road safety vision. The PIARC Road Safety Manual, 2003, included a Venn Diagram indicating the factors contributing to crashes (see Figure 2).

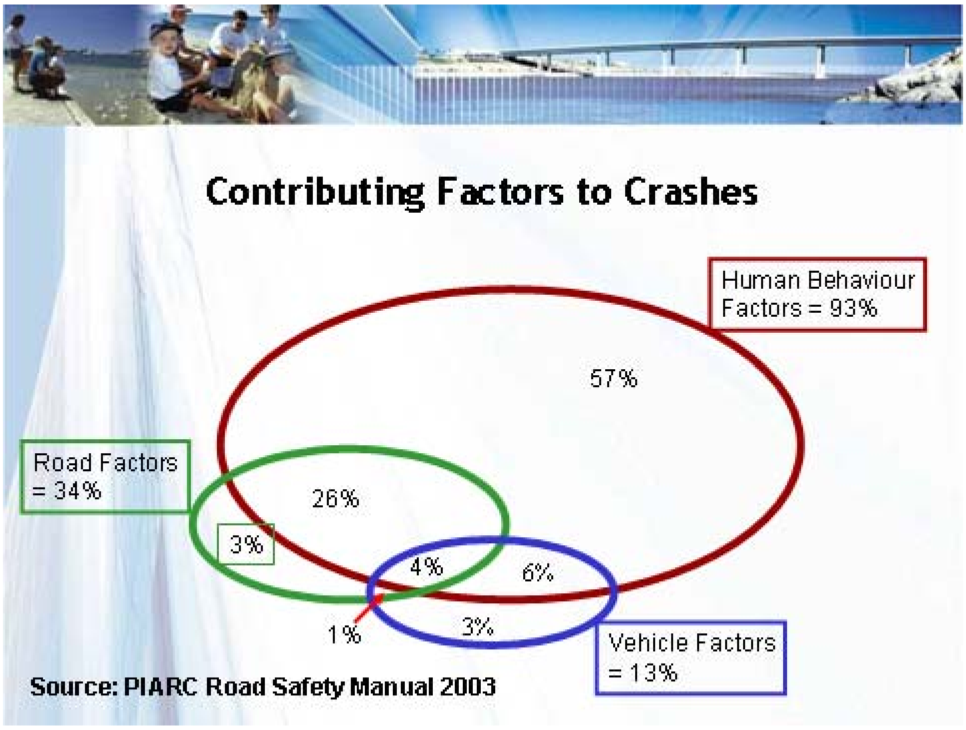

Figure 2: Contributing Factors to Crashes

From the Venn Diagram, one may take the perspective that education and enforcement regimes are required to address the ‘Human Behaviour Factors’. However, another perspective is that the Venn Diagram supports the view that vehicle and road treatments are more reliable than even disciplined human behaviour.

With time road and vehicle engineering may increasingly meet the tolerances for eliminating serious injury and death, reliably reducing road trauma in these areas (see Figure 3). Rather than focusing upon reducing human fallibility, it is proposed that we

[2] Towards Zero – Recommended Strategy, Road Safety Council’s Recommendation to Government to Reduce Road Trauma in Western Australia 2008 – 2020, August 2008.

should be focusing upon developing innovative road and vehicle engineering solutions that take human factors out of the equation for serious injury and death (see Figure 4). With time and innovation, it may then be conceivable that our road safety Vision could be achieved (see Figures 5 and 6).

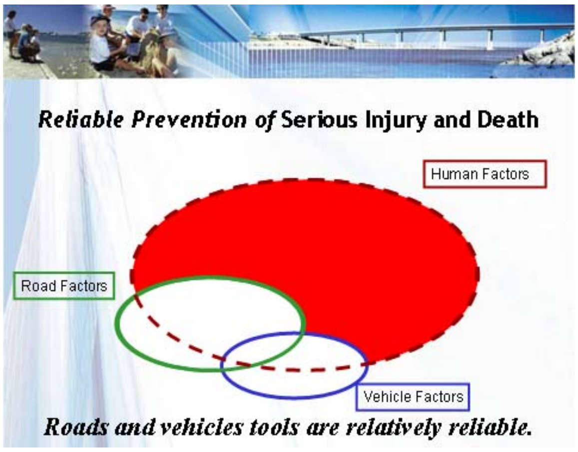

Figure 3: Reliable vehicle and road factors, unreliable humans.

Figure 4: Expanding the road and vehicle tool set.

Figure 5: Road and vehicle innovation takes more human factors out of the equation.

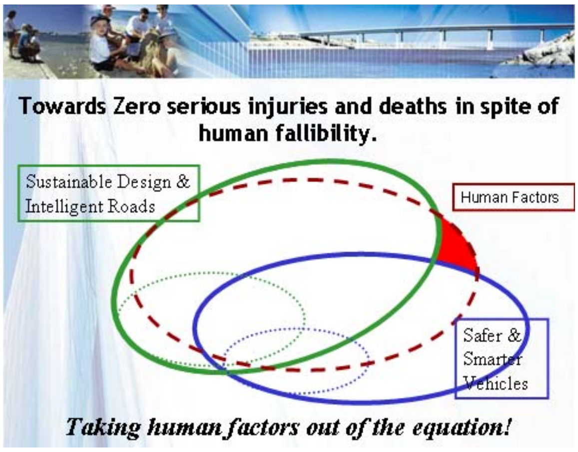

Figure 6: Road and vehicle engineering has a critical role in achieving the long term Vision.

In the road engineering context and at MRWA's New Perth Bunbury Highway (NPBH) road construction project, the Commissioner requested the project team aspire towards achieving zero deaths within the first five years of operation[3].

[3] Southern Gateway Alliance Road User Outcomes Workshop 9 February 2007.

The NPBH Safe Systems Working Group (SSWG) broadened the road safety Aspiration to 'zero serious injuries and deaths in the first five years of operation, in spite of human fallibility, due to sustainable solutions preventing the possibility'[4].

3. SAFE SYSTEM ENGINEERING

For consistency with the road safety Vision and Aspiration and to turn these statements around to a road engineering perspective, the Safe System Working Group proposed that roads should be designed to reduce collision energy/impulse to within human tolerances for serious injury and death when foreseeable crash scenario's arise[5]. The SSWG then considered the specific elements required to achieve this outcome through a procedure known as the Logical Framework[6].

3.1 Serious Injury and Death, Key Crash Types

The Safe Systems Working Group for New Perth Bunbury Highway considered the crash scenario's that most likely cause serious injury and death to be as follows:

- Run off road (a single vehicle leaves the road and collides with an obstacle or rolls over);
- At grade intersection (two conflicting vehicles colliding, predominantly side impact);
- Head on (two vehicles travelling in opposite directions collide); and
- Operational hazards (a broad category covering pedestrians, animals, weather conditions and traffic conditions)[7].

These were included in the 'Vision Zero' Logical Framework[8] (VZLF).

---

[4] 'Vision Zero' Logical Framework, development lead by Brendan Marsh, approved by the New Perth Bunbury Highway Safe Systems Working Group on 15 November 2007.

[5] 'Vision Zero' Logical Framework, row: Outcome, column: Narrative.

[6] AusGuideline 3.3, The Logical Framework Approach, Commonwealth of Australia 2005, October 2005.

[7] NPBH SSWG, Meeting 1 Workshop Summary, 12 September 2007.

[8] 'Vision Zero' Logical Framework.

3.2 Human Tolerances for Serious Injury and Death

'Advancing Sustainable Safety' documents the human tolerances for eliminating serious injury and death, and these align with the serious injury and death crash types (see Figure 7). These are specific road engineering design criteria that enable road planners and designers, to pursue the road safety Vision and Aspirations.

Road types combined with allowed road users	Safe speed (km/h)
Roads with possible conflicts between cars and unprotected road users	30
Intersections with possible transverse conflicts between cars	50
Roads with possible frontal conflicts between cars	70
Roads with no possible frontal or transverse conflicts between road users	≥100

Figure 7: Human tolerances for eliminating serious injury and death[9].

It is noted that 'roads with no possible frontal or transverse conflicts between road users' can potentially achieve safe speeds in excess of 100km/h.

The human tolerances for eliminating serious injury and death were included in the VZLF[10].

3.3 Sustainability

In application of the human tolerances for serious injury and death, other factors need to be considered as well, such as:

- Finite Budgets;
- Sometimes extensive road networks (e.g. MRWA);
- Environmental and social objectives; and
- Responsibility maximise the return on investments made.

When these factors are considered, it is recognised that with present technologies and techniques it can be impractical to achieve the human tolerances for serious injury and death. Therefore, road engineering 'solutions' that comply with the human tolerances for

---

[9] Advancing Sustainable Safety, National Road Safety Outlook 2005 – 2020, SWOV Institute for Road Safety Research, The Netherlands, 2006, edited by Fred Wegman and Letty Aarts.

[10] VZLF row: Outputs, column: Indicator.

eliminating serious injury and death should also pass ‘sustainability’ assessment criteria to achieve simultaneous improved economic, environmental and social outcomes. In fact, the VZLF states that:

A key element of ‘Vision Zero’ Policy is the development and application of *Sustainable Solutions* that can reliably prevent death and serious injury, in spite of human fallibility, and provide simultaneous triple bottom line community benefits[11].

This statement recognises the importance of Sustainability in road safety solution development and decision making.

3.4 Engineering Innovation

The need to apply sustainability assessment criteria enables scenario’s to exist where a *Sustainable Solution* is unavailable. It is common engineering practice for innovation processes to be applied to find new solutions to previously unsolved problems and these processes should be engaged.

For NPBH, the SSWG organised a ‘Vision Zero’ value management to initiate innovation, which:

- Included international and national experts in the prevention of serious injury and death including Roger Johannson (Swedish Road Administration), Bruce Corben (Monash University) and Raphael Gzrebieta (University of New South Wales) – with each expert presenting to the workshop;
- Included a presentation from the Commissioner of Main Roads on the principles included within the ‘Vision Zero’ Logical Framework
- Included a speech from the Executive Director of the Office of Road Safety and SSWG member, Iain Cameron, who challenged the group to find innovative solutions to the serious injury and death crash risks;
- Included a wide range of road engineering experts from the project design team and Main Roads participated;
- Sought to identify new solutions to the serious injury and death crash risks in accordance with the ‘Vision Zero’ Logical Framework; and
- Resulted in a long list of suggestions in each serious injury and death crash

[11] VZLF row: Goal, column: Narrative.

category.[12]

The report was approved by the SSWG[13] and presented to the Commissioner of Main Roads during a meeting with the SSWG. It was agreed the SGA would lead the detailed investigations into specific solutions applicable for NPBH and is to involve the SSWG who are to provide oversight and comment in accordance with the Vision Zero Logical Framework and value engineering principles.[14]

Despite time and advanced project progression being regularly documented as an issue during SSWG meetings, the outlined innovation process has resulted in real changes being applied to NPBH[15] including the major design amendment to the Old Coast Road approach to NPBH detailed in Figure 11. On this basis it is recommended that an appropriate innovation process be engaged to enable possible *'Sustainable Solutions'* to be identified and considered for all projects.

3.5 Hierarchy of Control

The VZLF records the following 'Outputs':

- 'Forgiving road and roadside design features that prevents the possibility of serious injury and death within a sustainability context.
- ITS pre-crash warning/intervention systems wherever reasonable to reduce 'Vision Zero' risks to a level that is "As Low as is Reasonably Practicable".
- Warning, regulatory and guidance driver aids.'[16]

These statements provide a framework for the management of serious injury and death crash risks as a "Hierarchy of Control" because the first statement represents the ultimate 'Sustainable Solution' that achieves the road safety Vision and Aspiration, the second statement is about significantly reducing crash risks and the third statement is

---

[12] 'Vision Zero' Road Safety, Value Management Workshop, Workshop Summary, 27 November 2007.

[13] SSWG Meeting 14, 21 February 2008.

[14] SSWG Meeting with Main Roads CMR, 10 March 2008.

[15] New Perth Bunbury Highway (NPBH, Safe Systems Working Group (SSWG) Meeting Minutes 27 October 2008.

[16] VZLF row: Outputs, column: Criterion.

about reducing crash risks (worst case scenario). For clarity, it is proposed that the Hierarchy of Control be reframed as follows:

- 'Sustainable Solution';
- Intelligent Transport Systems (ITS) alternative; and
- Education, enforcement and other road engineering alternative.

The Hierarchy of Control should be applied to mitigate serious injury and death crash risks, firstly seeking a 'Sustainable Solution', if unavailable, then an Intelligent Transport Systems alternative is sought to significantly reduce the crash risk and finally, the regular education, enforcement and other road engineering alternatives that reduce the crash risks should be considered.

4. SUSTAINABLE SOLUTIONS POSSIBILITIES

'Sustainable Solutions' possibilities have been identified and are being trialled around the world. Figure 8 demonstrates an urban design seeking to keep pedestrian precinct vehicle speeds beneath 30km/h. Figure 9 showcases the Swedish '2+1' concept used to prevent head on and run-off road crashes. Figure 10 demonstrates a low speed roundabout design for at grade intersections. Figure 11 demonstrates the approach design of Old Coast Road to NPBH.

Figure 8: Operational hazard – unprotected road user treatment.

Figure 9: '2+1' road for preventing run-off road and head on crashes.

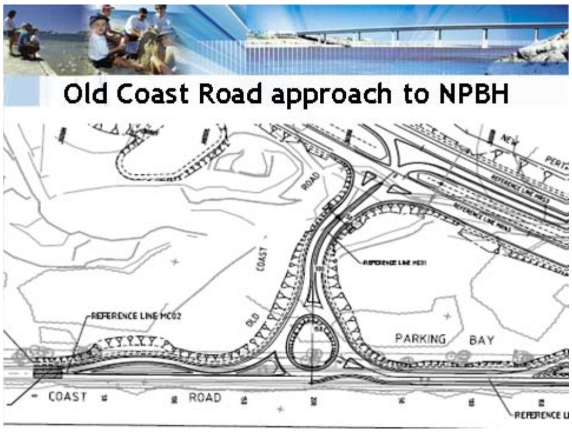

Figure 10: At grade intersection low speed roundabout.

Figure 11: Proposed Old Coast Road approach to NPBH.

Additional wire rope barrier is also being installed along NPBH to help reduce serious injury and death associated with run off road crashes.

5. ‘INTELLIGENT TRANSPORT SYSTEMS POSSIBILITIES

Intelligent Transport Systems (ITS) are systems that apply information, communications and control technologies to improve the operation and safety of transport networks[17]. Significant ITS development work is presently being undertaken as the underlying information, communications and control technologies themselves rapidly evolve, enabling more applications to be considered.

Many jurisdictions have recognised the importance of ITS. Japan has set some ambitious targets for 2020 capability, including zero serious injury and death, 50% reduction in greenhouse gas emissions and 50% reduction in congestion, predominantly through the development of ITS (see Figure 12)[18].

---

[17] PIARC Road Network Operation Handbook 2003.

[18] 'Vision-based Global Collaboration, for Asia Pacific ITS" by Prof Masao Sakauchi, ITS Asia Pacific Forum, Singapore 14 – 16 July 2008.

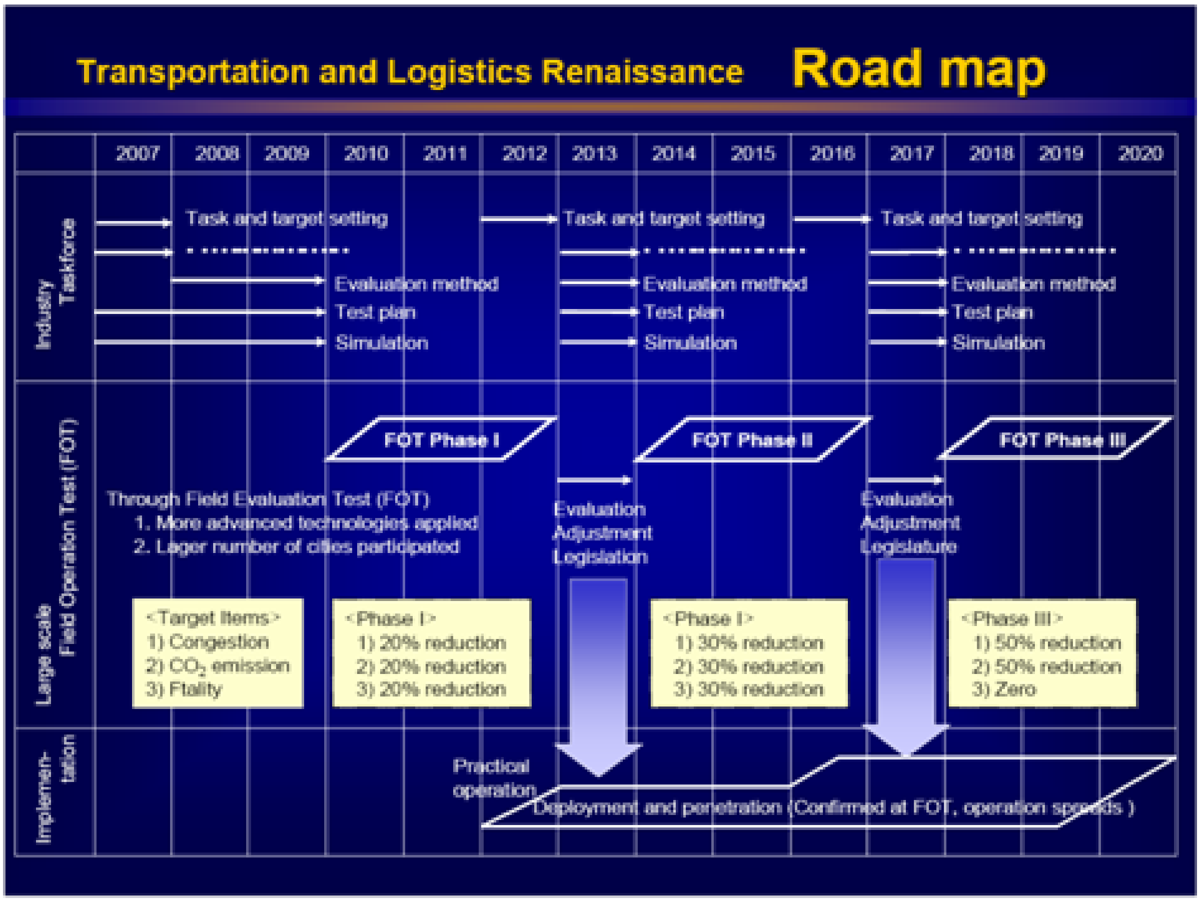

Figure 12: Japan's Transportation and Logistics Renaissance Roadmap.

Another example of this trend is Korea. Dr Kyong Soo-Yoo, President of Korean Institute for Intelligent Transport Systems, recently suggested that road design has not kept pace with vehicle design in recent decades and described a AU$250m research and development project seeking to develop a motorway achieving zero serious injury and death road safety together with operating speed of 160km/h.[19]

Australia and New Zealand also has an emerging Cooperative ITS program, through Austroads and the Network Taskforce. Figure 13 presents the proposed development phases and schedule as developed by Austroads Project NS1415, which is being lead by the Department of Queensland Main Roads.

[19] Joint REAAA, Austroads and Engineers Australia Transport Panel Engineering Seminar, Perth 22 October 2008, Perth Concert Hall.

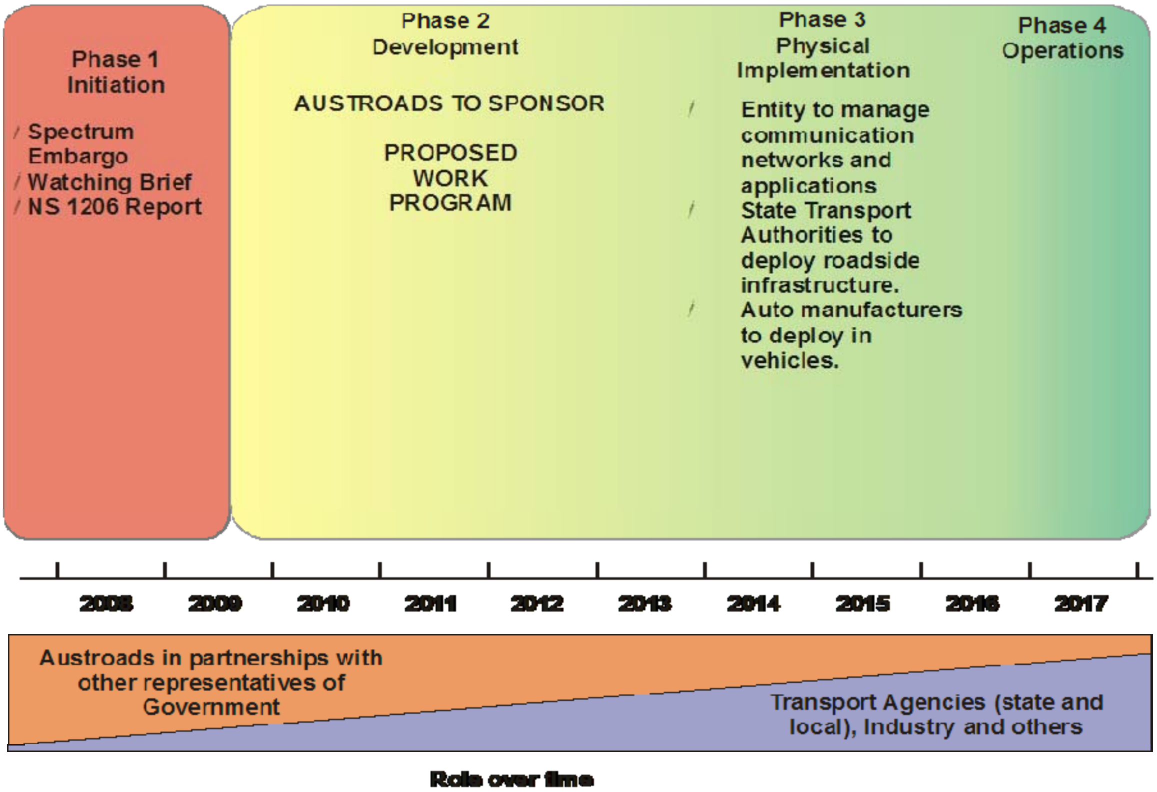

Figure 13: Austroads Cooperative ITS indicative development road map.[20]

While the future ITS development is considering intervention technologies, existing ITS can provide specific warnings and driver aids that significantly reduce the crash risk. For example, Germany has found that Variable Speed Limits on their autobahns can reduce severe injury rates by 30%[21].

At the NPBH project an Enhanced Intersection Warning System is under development to reduce the crash risk associated with the highest risk at grade intersections – see Figure 14. Detectors identify possibly conflicting vehicles and activate flashing beacons attached to standard warning signage.

[20] Austroads Project NS1415, Development of Management Arrangement and Identification of Pilot Applications for 5.9 ITS.

[21] StraBenforschung StraBenverkehrstechnik BMVBW in Germany.

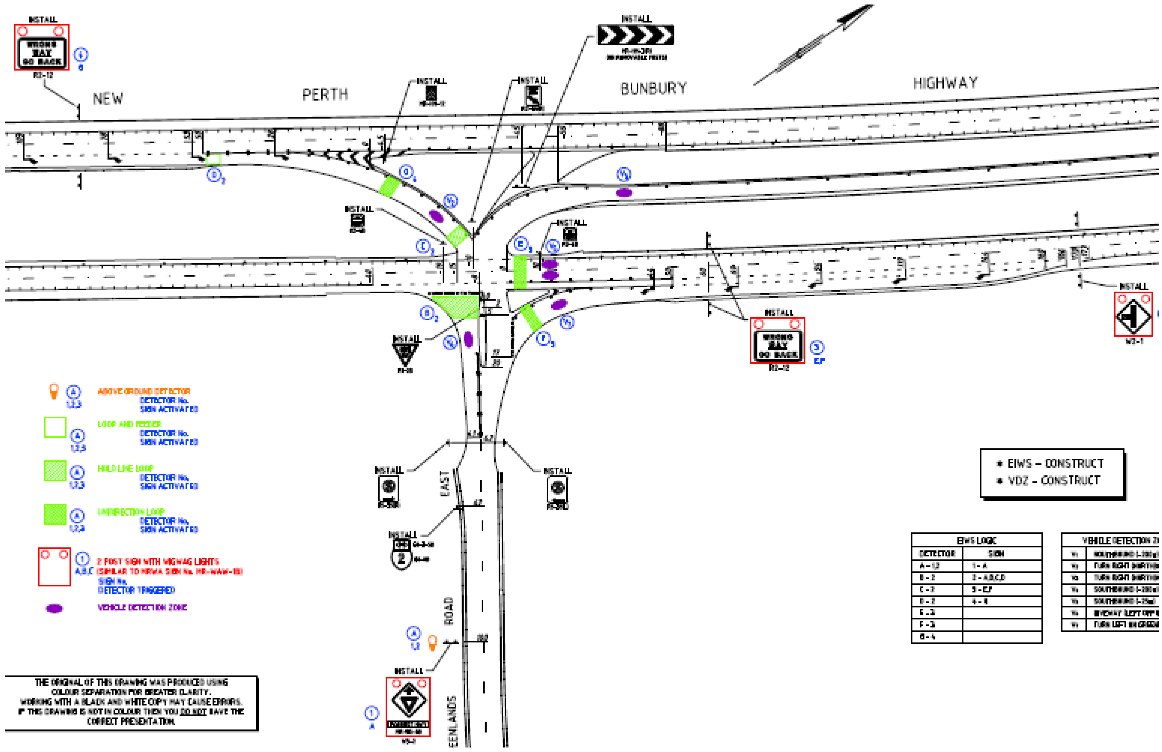

Figure 14: Enhanced Intersection Warning System proposal for the NPBH intersection with Greenlands Road.

ITS can also offer advanced enforcement and education functionality. For enforcement an example involves the point to point speed enforcement systems that are developing in other jurisdictions.

The ITS tool set is constantly evolving and expanding and should continue to be explored for opportunities to significantly reduce serious injury and death crash risks.

6. CONCLUSIONS

The strategic stakeholder engagement process employed at the Southern Gateway Alliance Project through the Sustainability & Partnership Team has enabled significant innovation, particularly in road safety and engineering. The innovative VZLF is an outcome of the process which converts the Safe System principles into a road engineering context. The application of the VZLF focused engineering effort into finding Sustainable Solutions for the key serious injury and death risks.

The key serious injury and death crash risks are ‘run-off road’, ‘intersection’, ‘head-on’ and ‘operational hazards. The known human tolerances for eliminating serious injury and death for each crash type are 70km/h, 50km/h, 70km/h and from 30km/h (unprotected road users) respectively. Engineering design that in spite of human fallibility prevents vehicle speeds exceeding the human tolerances for eliminating serious injury and death will generally eliminate serious injury and death through such designs. Accordingly, road engineering will play a significant role in achieving the associated visions and aspirations associated with road safety in the long term context due to the potential for ongoing reliable performance and known human fallibility.

Innovation processes should be applied to all road projects from the planning phase to identify possible solutions for keeping collision energies within human tolerances for eliminating serious injury and death when foreseeable crash scenario’s arise. Sustainability assessment processes should be applied to determine whether the possible solutions are sustainable, hence the term ‘Sustainable Solution’.

Where ‘Sustainable Solutions’ are not available, Intelligent Transport Systems (ITS) alternatives should be considered for significantly reducing the crash (and, therefore, serious injury and death) risk. Where ITS alternatives are also not available education, enforcement and other road engineering alternatives that reduce the crash risk should be considered. This approach represents the recommended Hierarchy of Control strategy for mitigating road network serious injury and death crash risks.